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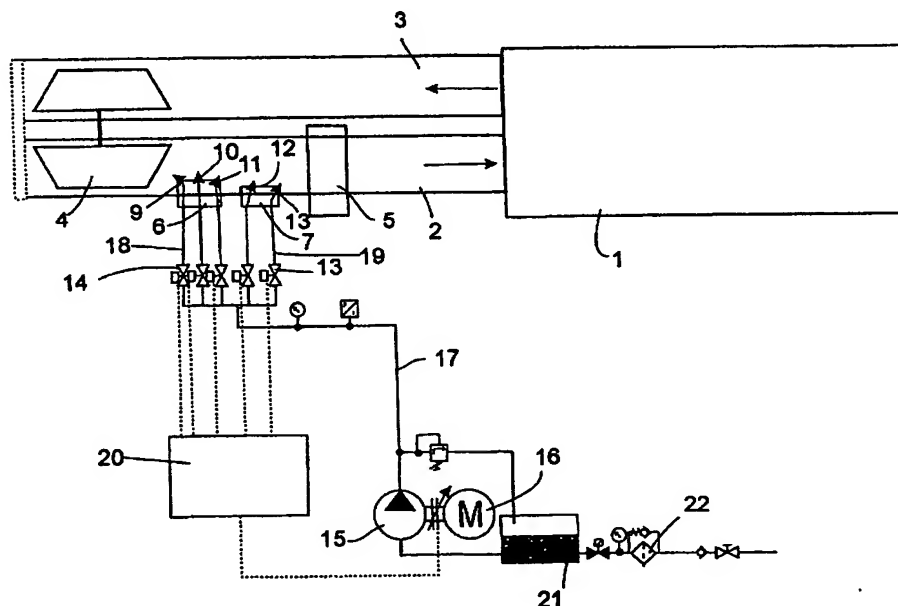
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(54) Title: **WATER SPRAYING SYSTEM**



(57) Abstract: A water spraying system, especially for the humidification of the intake air of a piston engine to reduce nitrogen oxide emissions, said system comprising at least one nozzle (9, 10, 11, 12, 13) for spraying an aqueous liquid mist into the air intake duct (2) and means for conveying the liquid to be sprayed to the nozzle. The system comprises means for accomplishing the injection of a spray of aqueous liquid mist to at least one point in the air intake duct (2) depending on the load and/or speed of rotation and/or temperature of the engine.

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WATER SPRAYING SYSTEM

Background of the invention

- 5 The present invention relates to a water spraying system as defined in the preamble of claim 1.

10 The invention concerns specifically a system for supplying an aqueous liquid mist into the intake air of a preferably turbocharged piston engine to reduce nitrogen oxide emissions (NO_x). At the high combustion temperatures, the combustion process in the cylinders of a piston engine produces nitrogen oxides, which are emitted together with the exhaust gas into the atmosphere. Because of the harmful climatic effects of nitrogen oxide emissions, efforts are undertaken to minimize their production.

15

As is known, adding water to the combustion process either in the form of water vapor or water droplets reduces the formation of nitrogen oxides. This phenomenon is based on a cooling effect. When the water

20 sprayed into the cylinder is evaporated, it reduces the temperature of the air in the cylinder while at the same time reducing the pressure. The pressure drop has an adverse effect on the efficiency, although the decrease of pressure and temperature has a favorable effect on the formation of nitrogen oxides. When the water is supplied in the form of

25 droplets together with the intake air, some of it is additionally wasted during the scavenging period and water consumption is increased. When air saturated with water vapor is supplied into the cylinder, the thermal capacity of the filling gas is increased and the gas has a substantially greater effect of reducing the temperatures of the combustion

30 process than does dry air. The effect of reducing the combustion temperatures increases with the water vapor concentration, yet without producing an undesirable effect on efficiency. Since an increase in the temperature of the gas supplied into the cylinder also augments the generation of nitrogen oxides as well as the consumption of water, it is

35 desirable to keep the gas temperature as low as possible, yet high enough to ensure that the gas supplied into the cylinder contains an amount of water vapor sufficient for the reduction of nitrogen oxides.

An apparatus for vaporizing a desired amount of water is disclosed in patents US 5758606 and US 6196165. A drawback with this apparatus is that the device mounted between the turbocharger and the cylinder
5 increases the cubic volume of the air intake ductwork, which has a considerable effect on the power output of the engine. The power output is dependent on the cubic volume after the turbocharger because during power increase or decrease the air pressure produced by the turbocharger increases the density of the air and the amount of gas supplied
10 into the cylinder. If the cubic volume between the turbocharger and the cylinder is increased, then it will take considerably longer before the amount of air produced by the turbocharger brings the pressure to the desired level and the power generated by the engine increases. Another drawback with the apparatus is that the heated water used for vaporization and flushed over the evaporation surfaces has the effect of increasing the temperature of the air. The device is unable to make use of the cooling effect produced in connection with the vaporization of the water, but the gas output from the device is at a relatively high temperature, so the amount of water vapor required for the reduction of nitrogen oxides and therefore also the water consumption are increased
20 considerably.

Specification WO98/10185 again discloses an apparatus in which the air produced by a turbocharger and the pressure of this air are utilized in
25 the injection of water for humidifying the air supplied to the turbocharger. A drawback with this system is the relatively low temperature of the supply air, which is why the amount of water vapor evaporated into the air remains small, and thus no significant nitrogen oxide reducing effect is achieved. Another drawback is that when the amount of
30 water is increased, the water droplets can not be evaporated after the air has reached a saturated state, with the result that the water droplets drift into the turbocharger and cause wear of the turbocharger vanes through droplet erosion. From a thermodynamical viewpoint, the drifting of droplets into the turbocharger is desirable as it reduces the
35 work performed by the turbocharger, increasing the pressure of the pressurized air produced at the output and simultaneously reducing its temperature. In practice, however, an air compressor rotating at a very

high speed - about 50 000 - 100 000 rpm - has proved to be very sensitive to droplet erosion as referred to above.

5 The object of the present invention is to achieve a water spraying system designed for supplying water mist into the air intake ductwork of especially a piston engine and allowing the drawbacks of prior-art to be avoided.

10 The system of the invention is mainly characterized in that the system comprises means for producing adjustable water mist spraying at at least one point in the air intake duct, depending on the load and/or speed of rotation and/or temperature of the engine.

15 The system of the invention is additionally characterized by what is stated in claims 2 - 17.

20 The solution of the invention has numerous significant advantages. In the apparatus of the invention, the above-described undesirable effects and deficiencies are eliminated by using adjustable water spraying, which is distributed to one or more points in the air intake duct by varying the number and/or size and/or quality of the nozzles used, depending on the load and temperature of the engine. According to the invention, the water flux is distributed to a number of small nozzles to make it possible to produce sufficiently small droplets and/or to distribute
25 such droplets over a larger area in the air intake duct so as to achieve an optimal vaporization. In the system of the invention, the spraying can also be focused on optimal points in the air intake ductwork where the temperature and/or air flow is highest. In the system of the invention, the number of nozzles spraying, the point and/or direction of injection
30 of the spray in the air intake ductwork can be varied according to the amount of water needed, e.g. on the basis of the load and/or speed of rotation of the engine. In the system of the invention, it is further possible to maintain a high nozzle pressure so as to keep the droplet size of the mist being sprayed sufficiently small. Furthermore, the system al-
35 lows the spraying to be varied between nozzles having different properties. The system of the invention produces an optimal droplet size of the liquid injected into the intake air. By using a nozzle cleaning system as

part of the water spraying system, very reliable operation of the system is achieved because the possibility of nozzles being clogged is avoided. By using pop-up nozzles as part of the system, the risk of the nozzles being clogged is further reduced. On the other hand, by using pop-up
5 nozzles, the nozzles are no impediment to the flow in the air intake duct when the system is out of use.

As the apparatus is connected directly to the structures of the air intake duct and it produces a fine mist directly without using any extra cham-
10 bers or other containers, it is able to make full use of the heat quantity required for the vaporization of the water, cooling the intake air at each spray injection point to a temperature close to the wet bulb tempera-
ture (or adiabatic saturation temperature, which in the case of a water-
air mixture is practically the same thing), i.e. to the temperature to
15 which the air temperature can be reduced by vaporization of water. As connecting the apparatus of the invention to a turbocharged engine does not involve any changes in the cubic volume of the air intake system, it has no adverse effect on the power output of the engine, either.

20 Another advantage of the invention is that the humidity of the intake air can be increased stepwise after each heat supply point, thus adjusting the humidity of the gas fed into the cylinder and therefore the formation of nitrogen oxides within desired limits.

25 **Brief description of the figures**

In the following, the invention will be described in detail by the aid of an example with reference to the attached drawings, wherein

30 Fig. 1 presents a system according to the invention in connection with a turbocharged piston engine,

Fig. 2a, 2b presents sectioned view of a spraying head in the system of the invention,

35 Fig. 3a presents a diagram of a control system of the spraying system of the invention,

Fig. 3b presents a graph representing the operation of the system in Fig. 3a,

- 5 Fig. 4 presents a spraying system according to the invention and a cleaning system utilized in the spraying system, and

Fig. 5 presents a diagram of a system according to the invention.

10 Detailed description of the invention

As stated, the invention concerns a water spraying system, especially for humidification of the intake air of a piston engine 1 to reduce nitrogen oxide emissions, said system comprising at least one nozzle 9, 10, 15 11, 12, 13 for spraying an aqueous liquid mist into the air intake duct 2 and means 21, 15, 17, 18, 9 – 13 for conveying a liquid to the nozzle. The system comprises means for producing adjustable water spraying at at least one point in the air intake duct 2, depending on the load and/or speed of rotation and/or temperature of the engine. In the system, 20 the amount of water (water flux) to be injected into the air intake duct 2 is distributed to a number of nozzles 9, 10, 11, 12, 13. The water flux is typically distributed to a plurality of small nozzles to achieve a small droplet size. The amount of water to be injected is distributed in the air intake duct 2 over a larger area to accomplish an optimal vaporization, 25 preferably at points where the temperature and/or air flow rate is high, preferably highest, or in the vicinity of such points. In the system, the number of nozzles spraying 9, 10, 11, 12, 13 is adapted/adaptable according to the required amount of water to be sprayed. The point and/or direction of injection of the water mist spray 30 is adapted/adaptable according to the required amount of water to be injected. The system is designed to maintain a high nozzle pressure to keep the spraying liquid's droplet size small. The system preferably comprises nozzles 9, 10, 11, 12, 13 having different properties, permitting the number of and/or nozzle type of the nozzles spraying to be varied 35 according to the amount of water required. Several nozzles 9, 10, 11; 12, 13 in the system may be arranged on the same mounting frame

6, 7. The system comprises control equipment by means of which the spraying action of at least some of the nozzles 9 – 13 can be adjusted.

5 The system comprises at least one valve element 13, 14, by means of which the liquid flow passage to the nozzle 9 – 13 is adjusted and/or opened/closed. The system comprises a control system which maintains an at least nearly constant pressure or a predetermined pressure level in at least one supply pipe 17 leading to the nozzles regardless of the
10 output of the pump 15. An embodiment of the system comprises an output regulating pump unit which controls the pressure so that the pressure in at least one supply pipe leading to a nozzle is constant. Another embodiment of the system employs a control system which comprises a constant-output pump and controls the pressure by means of a valve system to produce a constant pressure in at least one supply pipe
15 leading to a nozzle. The system further comprises a system for cleaning the nozzles and/or keeping the nozzles clean.

Fig. 1 is a diagrammatic representation of a system/apparatus according to the invention, installed in connection with the air intake duct 2 of
20 a piston engine, such as a diesel engine. The air intake duct 2 and the exhaust gas duct 3 are shown in a simplified form in the figure. The engine presented in the figure is provided with intake air compressor 4, which feeds air under positive pressure into the air intake ductwork 2 of the engine. To reduce the nitrogen oxide emissions of the engine, the
25 air intake ductwork is provided with at least one nozzle 9 – 13 fitted to supply water mist into the intake ductwork 2. In the case illustrated in the figure, the intake ductwork is also provided with a heat exchanger element 5, such as a charge-air intercooler, which also functions as a heater.

30

At least one of the nozzles in the spraying system is connected directly to the structures of the air intake duct 2, and a fine mist is produced directly into the intake air in the air intake duct by means of its nozzle head 6, 7 comprising at least one nozzle. When the solution of the invention is used, no extra chambers or other containers need to be provided in the air intake ductwork. The nozzles feed water mist under a
35 high pressure into the air intake duct. The apparatus comprises means

for producing the required amount of water to the desired pressure and to achieve a droplet size as favorable as possible. The pressure in the liquid supply piping is typically over 10 bar, preferably over 30 bar, most preferably over 50 bar. The pressure may be typically between 10
5 - 300 bar. The liquid, especially aqueous liquid injected into the air intake ductwork is a fine mist. 50 % of the water volume (Dv50) is in the form of droplets typically having a droplet size below 200 micrometers, preferably below 100 micrometers and more preferably below 50 micrometers. Under high load conditions, the droplet size may be larger.

10 The system comprises means for supplying an aqueous liquid to the nozzles. In the embodiment presented in Fig. 1, the system comprises a liquid source 21, from where the liquid is pumped through a pipe 17 by means of a pump 15. The pump is operated by a drive 16. The pump is
15 typically a high pressure pump, e.g. a displacement pump. The liquid can be directed via channels 18, 19 to different nozzles 9 - 13. As shown in Fig. 1, several nozzles 9-11; 12-13 can be connected to the same mounting frame 6, 7. The mounting frame 6, 7 presented in the figure has a separate channel for each one of the nozzles 9, 10, 11, 12,
20 13. This makes it possible to control the pressure and/or flow of the pressure medium supplied to each nozzle 9, 10, 11, 12, 13 individually. According to another embodiment of the invention, the nozzles of the spraying head can be arranged in groups so that one feed channel leads to several nozzles. The nozzles in the spraying head may have different
25 properties, which have been adapted according to the placement of each nozzle. The form of the spraying head, the number of nozzles and their orientation may vary depending on the application. It is also possible to supply different mediums to the nozzle, such as water and gas. The figure does not show the nozzles in detail, but they may be re-
30 placeable depending on the application. The nozzles are therefore of a type such that they produce a spray of fine mist when supplied with liquid under a high pressure. Many kinds of nozzles of this category are known, e.g. from fire extinguishing technology employing water mist. For example, specifications WO 92/20454 and WO 94/06567 disclose
35 nozzles that produce a water mist at a high pressure. Naturally, other types of nozzles may also be used, e.g. specification WO 01/45799 discloses yet another nozzle.

The flow direction of the intake air in the intake ductwork 2 is indicated by an arrow in the figure.

- 5 The direction of injection of the liquid mist sprayed through the nozzles is typically so selected that a maximal relative difference of velocity and temperature is achieved.

10 The amount of water supplied through the nozzles typically increases with increasing engine load. Thus, when the engine load is low, it is possible to supply water only to some of the nozzles and increase the number of nozzles spraying when the load increases. Similarly, the spraying head can be provided with nozzles having different properties, such as flow rate, droplet size produced by the nozzles, etc. It is thus
15 possible to form different combinations which can be adapted to a wide range of different applications, different engine types, different placements and conditions.

Typically, the amount of water supplied through the nozzles increases
20 as the engine load increases. This can be implemented e.g. by using a control system whereby the speed of rotation of the pump 16 is increased by the drive device driving the pump. This increases the pressure in the supply piping 17 and, based on data provided by a pressure transmitter, liquid flow passages 18, 19 are opened for more nozzles 9
25 – 13 and/or a nozzle having a greater spraying capacity is engaged by opening a liquid flow passage for it. Similarly, when the load decreases, the liquid flow passages are closed for some of the nozzles and/or a nozzle with a lower spraying capacity is engaged. Correspondingly, an arrangement can be used such that, when the load is low, liquid is in-
30 jected from nozzles producing a smaller droplet size, and when the load increases, the droplet size is increased, e.g. by opening a liquid flow passage to nozzles producing larger droplets. It is also possible to use an arrangement such that, in low-load conditions involving a lower temperature, the pressure in the supply piping is higher, smaller droplets
35 being thus produced by the nozzle when the load is small.

The control can also be implemented by using constant power control to control the pump unit. The power of the pump unit equals the pressure in the piping multiplied by the quantity of liquid flowing per unit of time ($P[\text{kW}] = p[\text{bar}] * Q[\text{l/min}] = \text{constant}$). This control mode aims at keeping the power of the pump unit constant. When the rate of flow increases, the pressure is reduced and vice versa, so that the power remains substantially constant or nearly constant.

The embodiments described above are only examples. Accordingly, in some embodiments the amount of water supplied is reduced according to engine load.

The apparatus of the invention is able to make full use of the quantity of heat required for the vaporization of the water, cooling the intake air at each spray injection point to a temperature close to the wet bulb temperature (or adiabatic saturation temperature, which in the case of a water-air mixture is practically the same thing), i.e. to the temperature to which it is possible to reduce the air temperature by vaporization of water.

In the apparatus of the invention, the humidity of the intake air is preferably increased stepwise after each heat supply point. In the direction of the intake air flow, water mist is injected before the last heat supply point, which can advantageously be used as a water evaporation surface. By this arrangement, the humidity of the gas fed into the cylinder and therefore the formation of nitrogen oxides is regulated within the desired limits.

The apparatus comprises a system required for the control of the amount of water to be injected, by means of which the amount of water to be evaporated into the intake air and the cooling of the intake air can be controlled. The apparatus comprises valve elements 13, 14 arranged in connection with the liquid flow passages leading to the nozzles, e.g. in connection with the pipes 18, 19. The valves 13, 14 are typically controlled by a control system 20, allowing the liquid flow passages 18, 19 to be opened and closed as necessary.

Fig. 2a and 2b present an embodiment of a spraying head that can be utilized in the system. The spraying head 201 for humidifying the intake air of a piston engine comprises at least one nozzle 203 and one channel 211 for feeding a liquid humidifying the intake air into the air intake duct 205 or into a space leading to the air intake duct. The spraying head is movable between at least two positions, a first position, in which first position the spraying head is retracted, and a second position, in which second position the spraying head 201 is protruding. In the non-active state, in the first position (Fig. 2a), the spraying head is in a retracted position, whereas in the active state, in the second position (Fig. 2b), at least one nozzle 203 of the spraying head extends to a position inside the air intake duct relative to the level of the interior surface of the air intake duct 205 and/or the edges of the spraying head holder 202.

The holder 202 is provided with at least one guide element 213, and the spraying head, preferably its shank part 207, with at least one mating surface 214 matching the guide element for keeping the spraying head in the desired orientation. The guide element 213 is e.g. a groove to which a ridge in the shank element, aligned in the direction of motion, is fitted. The guide element may also consist of e.g. rolling elements, such as balls or rollers, with a counter element 214 movably fitted between these.

The spraying head 201, preferably its shank part 207, and the holder 202 are arranged to function as a cylinder-piston combination in which the spraying head, preferably its shank part 207, is provided with a piston part 206 and the holder 202 comprises a cylinder chamber 208, the piston part being movably fitted in it. In the embodiment in Fig. 2a, pressure medium is supplied from the inlet 209 through a pipe element (not shown) into the cylinder chamber space below the piston 206 from the distant end 216 of the holder 202 relative to the air intake duct 205. By the action of the pressure medium, the piston moves upwards in the figure, thereby causing the spraying head 201 mounted on the shank part 207 to move to the second position shown in Fig. 2b. The pressure medium is thereby admitted from the chamber 208 via the channel 211 provided in the shank part 207 to the nozzle 203, from where it is in-

jected into the air intake duct. The channel 211 is typically provided with a throttle element 217. The piston part 206 is provided with a sealing element 212 or equivalent to provide a sliding fit between it and the interior surface of the cylinder chamber 208.

5

Arranged in connection with the spraying head are means for moving the spraying head 201 from the protruding position into the retracted position. Typically, the system comprises a spring element 210 arranged between the spraying head 201 and the holder 202 to move the
10 spraying head from the protruding position to the retracted position. The spring element is preferably placed between the piston element 206 and the end piece of the holder part 202 adjoining the air intake duct 205. The spring is a helical spring, which is compressed when the nozzle head moves into the protruding position. When the pressure of the
15 pressure medium acting on the piston falls below the desired value, the spraying head is moved to the retracted position by the action of the spring force and/or a possible pressure acting in the air intake duct.

The spraying head is secured to the wall 205 of the air intake duct typically by a rigid joint, using e.g. fastening means 204, such as screws or
20 bolts, at its flange 215. The wall 205 of the air intake duct is provided with an opening for the spraying head. In the embodiment in Fig. 2a, the spraying head, at least its nozzles 203, as seen in the direction of motion of the spraying head, remain outside the imaginary surface
25 formed by the inner edges of the opening in the wall of the air intake duct, i.e. the edges on the interior side of the air intake duct. If the spraying head is of a substantially cylindrical form, then the nozzles typically open to the cylindrical surface. Similarly, if the spraying head has a conical form, then the nozzles open to the conical surface. Typi-
30 cally, the nozzles open to the lateral surface of the spraying head.

Fig. 3a presents a diagram schematically representing the control arrangement used in the water spraying system of the invention. The system comprises at least two nozzles 301a, 301b, 301c, 301d, which are
35 disposed in the engine's air intake duct (not shown) or in a corresponding space leading to the combustion chamber of the engine for humidifi-

cation of the intake air. In the case presented in the figure, four nozzles are shown, with a channel 302a, 302b, 302c, 302d leading to each nozzle from a supply pipe 304 supplying a pressure medium, preferably an aqueous liquid. The pressure medium is fed into the supply piping by a pump 306, driven by a drive device 307. The pump pumps the pressure medium from a pressure medium source 310, such as tank. Reference numbers 308 and 309 indicate a pipe and a relief valve through which the liquid can flow in case the pump pressure and the pressure in pipe 308 exceed a certain presettable limit value. Reference numbers 313 and 315 indicate valves, and reference number 314 indicates a filter. The filter prevents particles that might clog the valves 301a, 301b, 301c, 301d of the spraying head from entering the spraying system. When the liquid surface in the container 310 falls below a certain level, a level switch 311 will open valve 313. Switch 324 will close the valve when the water level in the container 310 has risen to a given height.

The pump 307 is preferably a constant-output pump which always pumps the same amount Q of pressure medium per unit of time into the supply pipe 304 when running. The pump drive is preferably a motor, such as an electrically operated direct-current motor, which drives the pump at a constant speed. The channels 302a, 302b, 302c, 302d leading to the nozzles are provided with valve elements A1, B1, C1, D1, which can be opened and closed as instructed by the control system. The control system typically controls the valves A1, B1, C1, D1 according to the required amount of liquid to be sprayed, preferably according to the engine load, so the amount of liquid supplied into the intake air typically increases with the engine load. The system comprises a return pipe 305, through which the liquid quantity not fed into the intake air returns to the tank 310. Disposed between the supply pipe 304 and the return pipe 305 are valve elements A2, B2, C2, D2, which can be opened and closed as instructed by the control system. For each closed feed channel 302a, 302b, 302c, 302d of the nozzles 301a, 301b, 301c, 301d, a corresponding channel 303a, 303b, 303c, 303d opening into the return pipe 305 is provided. If all the nozzle feed channel valves A1, B1, C1, D1 are open, then the valves A2, B2, C2, D2 in the flow passages leading to the return pipe 305 are closed, and vice versa. The sum of the k -values of the return channels substantially corresponds to

the sum of the k-values of the closed nozzles and those of their feed channels. In the embodiment represented by Fig. 3, each channel 303a, 303b, 303c, 303d leading into the return pipe 305 is provided with a throttle element, which is adjusted to match the k-value of the nozzle in closed state. Thus, the sum of the k-values in the system remains substantially constant. In the case of Fig. 3, valve element A1 in the feed channel 302a leading from the supply pipe to valve 301a is open, thus allowing the liquid to flow to the nozzle. The valves B1, C1, D1 in the feed channels leading to the other valves are closed, thus preventing liquid flow to valves 301b, 301c, 301d. Correspondingly, valve A2 in the channel 303a leading to the return pipe 305 is closed, preventing liquid flow through channel 303a into the return pipe. Valves B2, C2, D2 in the other channels 303b, 303c, 303d arranged between the supply pipe and the return pipe are open, permitting the liquid to flow through them into the return pipe 305. The channels are provided with a throttling element 317b, 317c, 317d or equivalent, which corresponds to the k-values of the closed nozzles. By providing nozzles having different characteristics and different flow rate capacities, a very large control range can be covered accurately. In the case of Fig. 3, by using a pump with an output capacity of 15 l/min, where nozzle 301a has an output of 1 l/min, nozzle 301b an output of 2 l/min, nozzle 301c an output of 4 l/min and nozzle 301d an output of 8 l/min, the entire range of 1 – 15 l/min can be covered by opening and closing the valves. Fig. 3b visualizes the quantity of water Q supplied into the air intake duct as a function of engine load (Load). The pressure is typically constant in the system. When the engine load increases, the amount of liquid flowing into the intake air through the nozzles is increased by increasing the number of nozzles and/or by selecting a nozzle that permits a larger liquid quantity to flow through it in a unit of time. When the engine load decreases, the amount of liquid flowing through the nozzles supplying liquid into the intake air is reduced by reducing the number of nozzles and/or by selecting a nozzle that permits a smaller amount of liquid to flow through it in a unit of time. In connection with the above-described operation, the amount of water supplied into the return pipe by the "by-pass" route is correspondingly adjusted in inverse proportion to the amount of water fed through the nozzles. In a corresponding manner, the throttling is adjusted so that at least when liquid is being injected into the

intake air in the system, the sum of the k-values (Σk) remains substantially constant regardless of whether the liquid is passed through the nozzles or through the return pipe or whether a portion of the liquid quantity is passed through the nozzles and another portion, substantially the rest of it through the return pipe. The flow rate for a nozzle is given by the formula $Q = kv/p$, where Q is the flow rate, p is the pressure forcing the medium through the nozzle and k is the nozzle resistance. The value of the factor k depends on the area of the nozzle aperture, among other things. In the case of circular aperture, the value of the factor k depends on the aperture diameter d according to the equation $k = 0.78 \cdot d^2$ when the aperture is a so-called short aperture. The resistance of the return pipe is adapted to correspond to the resistance of the closed nozzles. The liquid flowing back in the return pipe 305 can also be circulated via a heat exchanger, which makes it possible to utilize the heat of the liquid and/or to supply more heat to it via the heat exchanger. The return pipe 305 may also be provided with a filter element to filter out impurities from the circulated liquid. Naturally the water coming from the liquid source can also be passed through a filter element to remove at least some of the impurities.

The system may additionally comprise means for producing pressurized air to further reduce the droplet size. The system may further comprise equipment designed for producing pressurized air, by means of which the nozzles are cleaned after use, preventing them from becoming clogged. Fig. 4 presents a cleaning system in a water spraying system, especially in a water spraying system designed for the humidification of intake air, which comprises at least one spraying nozzle 401a, 401b, 401c, 401d for injecting liquid into the intake air. The apparatus comprises means 420, 421, 425a, 425b, 425c, 425d for supplying a second pressure medium to the nozzle 401a, 401b, 401c, 401d after the supply of a first pressure medium, such as a liquid and/or gas intended for the humidification of the intake air to the nozzle has been interrupted, to prevent clogging of the nozzle. The apparatus comprises a pressure medium source, such as a pump 420 pumping pressurized air, and means for conveying the pressure medium from the pressure medium source to the nozzle 401a, 401b, 401c, 401d. For conveying the second pressure medium, a pipeline 421, 425a, 425b, 425c, 425d connected in

the nozzle feed channel 402a, 402b, 402c, 402d between the valve element A1, B1, C1, D1 and the nozzle 401a, 401b, 401c, 401d is used. Each pipeline 425a, 425b, 425c, 425d used for supplying the second pressure medium is provided with a check valve 423 to prevent the first
5 pressure medium from flowing through the supply channel to the other nozzles and/or to the pressure medium source. The second pressure medium is a liquid and/or gas.

Fig. 5 presents yet another embodiment of the water spraying system
10 of the invention. It comprises nozzles 1a, 1b, 1c, 1d arranged in feed channels 2a, 2b, 2c, 2d, each channel having a different number of nozzles placed at different positions in the air intake duct K. In this embodiment, too, the valve elements A1-A2, B1-B2, C1-C2, D1-D2 controlling the liquid flow going into the nozzle feed channels 2a, 2b, 2c, 2d
15 and the return channel 3a, 3b, 3c, 3d are controlled in pairs. These valve element pairs are most appropriately controlled by means of solenoid valves A1', B1', C1', D1'. The return channels are provided with variable throttles 17a, 17b, 17c, 17d, by means of which the flow can be adjusted as desired. Correspondingly, the pressure can also be varied
20 by opening and closing the throttle elements in the return channel. In this embodiment, the valve elements and throttles are arranged as control blocks, indicated in the figure by the number 39 and a broken line. This embodiment likewise comprises a nozzle cleaning system, in which a pressure medium, such as pressurized air, is supplied from a
25 pressure medium source via a pipeline 21 by means of a pump. The pressure medium supply line 21 of the cleaning system is provided with a variable throttle element for the control of the flow. The control system further comprises a temperature regulating system, whereby the temperature of the liquid to be injected can be adjusted. The system
30 comprises a heat exchanger element 33 arranged in the return line 5, to which heat can be supplied via a line and valve 38. When a small amount of liquid is to be injected, most of the liquid quantity supplied by the pump returns back via the return line. The pressure is at least partly converted to heat as it passes through the throttle elements 17a
35 - 17d, the liquid entering the return line being thus heated. From the return line, at least some of the liquid can be conveyed directly to the pump 6 or into the tank 10. In this case, the heat exchanger element

33 may be superfluous because the system itself generates sufficient heat in the liquid. Similarly, the heat exchanger 33 may also recover heat and transfer it to another part. The return line 5 is also preferably provided with a filter element 34 for removing impurities from the liquid.

In the system of the invention, some other pressure medium, such as gas, preferably air, can also be supplied into the liquid. In this case, a solution of the same type as e.g. in Finnish patent application FI 20010514, which is as yet unpublished on the date of application of the present application.

It is obvious to the person skilled in the art that the invention is not limited to the embodiments described above, but that it may be varied within the scope of the claims presented below.

Claims

1. Water spraying system, especially for the humidification of the intake air of a piston engine to reduce nitrogen oxide emissions, said system comprising at least one nozzle (9, 10, 11, 12, 13) for spraying an aqueous liquid mist into the air intake duct (2) and means for conveying the liquid to be sprayed to the nozzle, characterized in that the system comprises means for accomplishing the injection of a spray of aqueous liquid mist to at least one point in the air intake duct (2) depending on the load and/or speed of rotation and/or temperature of the engine.
2. Water spraying system according to claim 1, characterized in that the amount of aqueous liquid to be sprayed into the air intake duct (2) is distributed in the system to several nozzles (9, 10, 11, 12, 13).
3. Water spraying system according to claim 1 or 2, characterized in that the amount of aqueous liquid to be sprayed is distributed in the air intake duct (2) over a larger area to achieve an optimal vaporization, preferably to points with a high temperature and/or air flow or to their vicinity.
4. Water spraying system according to any one of claims 1 – 3, characterized in that the number of nozzles (9, 10, 11, 12, 13) in the system is adapted according to the required amount of liquid to be sprayed.
5. System according any one of claims 1 – 4, characterized in that the point of injection and/or direction of injection of the spray of liquid mist is adapted according to the required amount of aqueous liquid to be sprayed.
6. System according any one of claims 1 – 5, characterized in that the system comprises nozzles (9, 10, 11, 12, 13) having different properties, the number and/or type of nozzles spraying being varied according to the amount of liquid required.

7. System according any one of claims 1 – 6, characterized in that the several nozzles (9 – 13) in the system are arranged on the same mounting frame (6, 7).

5 8. System according any one of claims 1 – 7, characterized in that the system comprises a regulating apparatus, by means of which the injection action of at least some of the nozzles (9 – 13) can be controlled.

10 9. System according any one of claims 1 – 8, characterized in that the system comprises at least one valve element (13, 14), by means of which the liquid flow passage leading to one of the nozzles (9 – 13) is adjusted and/or opened/closed.

15 10. System according any one of claims 1 – 9, characterized in that the system comprises a regulating system, by means of which the pressure in at least one supply pipe (17) leading to the nozzles is kept at least nearly constant or at a predetermined level independently of the output of the pump.

20 11. System according any one of claims 1 – 10, characterized in that the system comprises an output regulating pump unit, by means of which the pressure is regulated by pressure control so that the pressure in at least one supply pipe (17) leading to a nozzle is constant.

25 12. System according any one of claims 1 – 10, characterized in that the system comprises a control system comprising a constant-output pump and controlling the pressure by means of a valve system to maintain a constant pressure in at least one supply pipe leading to a
30 nozzle.

13. System according any one of claims 1 – 12, characterized in that the system further comprises a system for cleaning the nozzles and/or keeping the nozzles clean.

35 14. System according any one of claims 1 – 13, characterized in that the pressure in the liquid supply piping is 10 – 300 bar.

15. System according any one of claims 1 – 14, characterized in that the droplet size of the water mist is typically below 200 micrometers.

5

16. System according any one of claims 1 – 15, characterized in that a second pressure medium, typically a gas, preferably air, is supplied to at least one nozzle.

10

17. Apparatus according any one of claims 1 – 16, characterized in that the apparatus comprises means for controlling the temperature of the liquid to be injected.

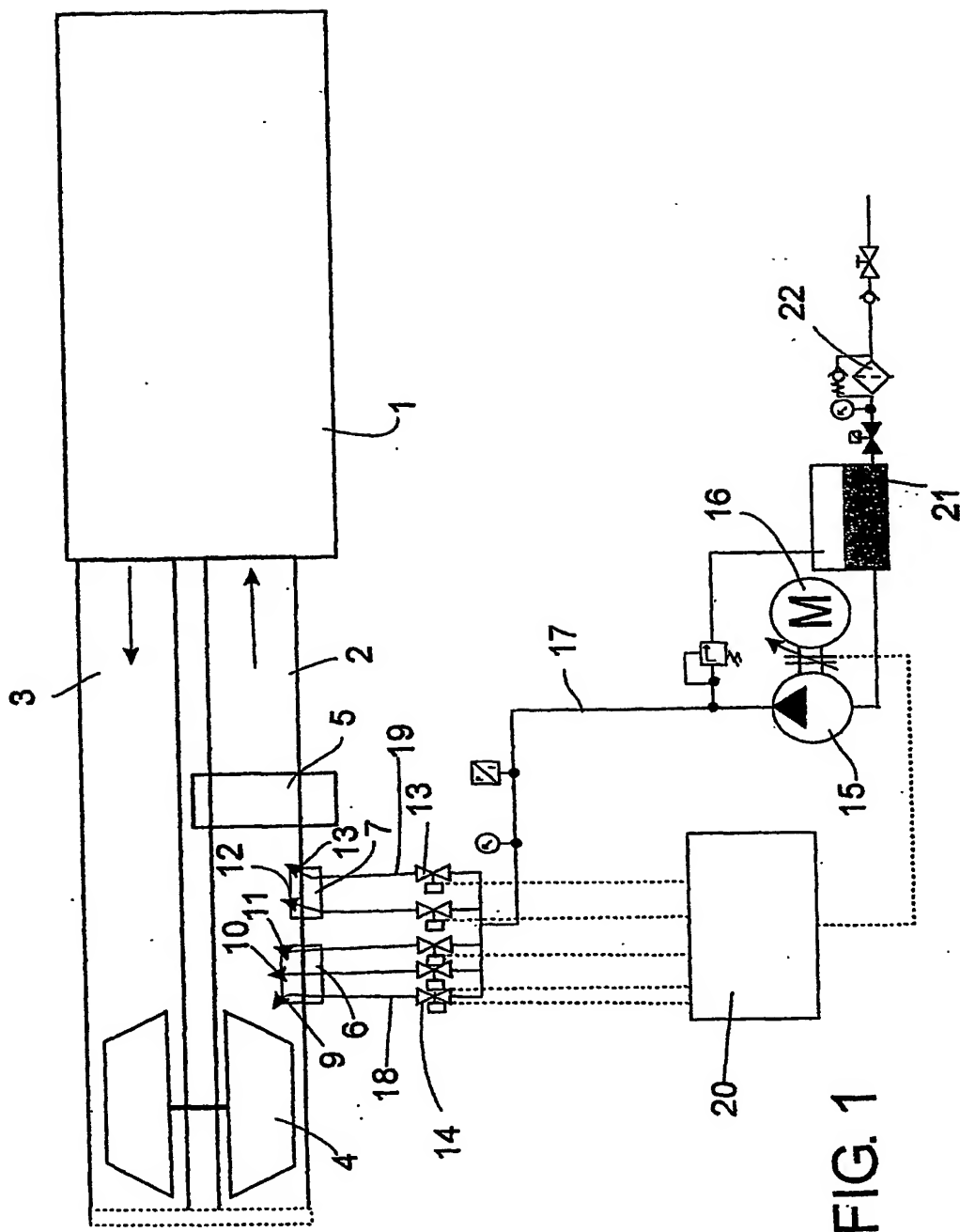


FIG. 1

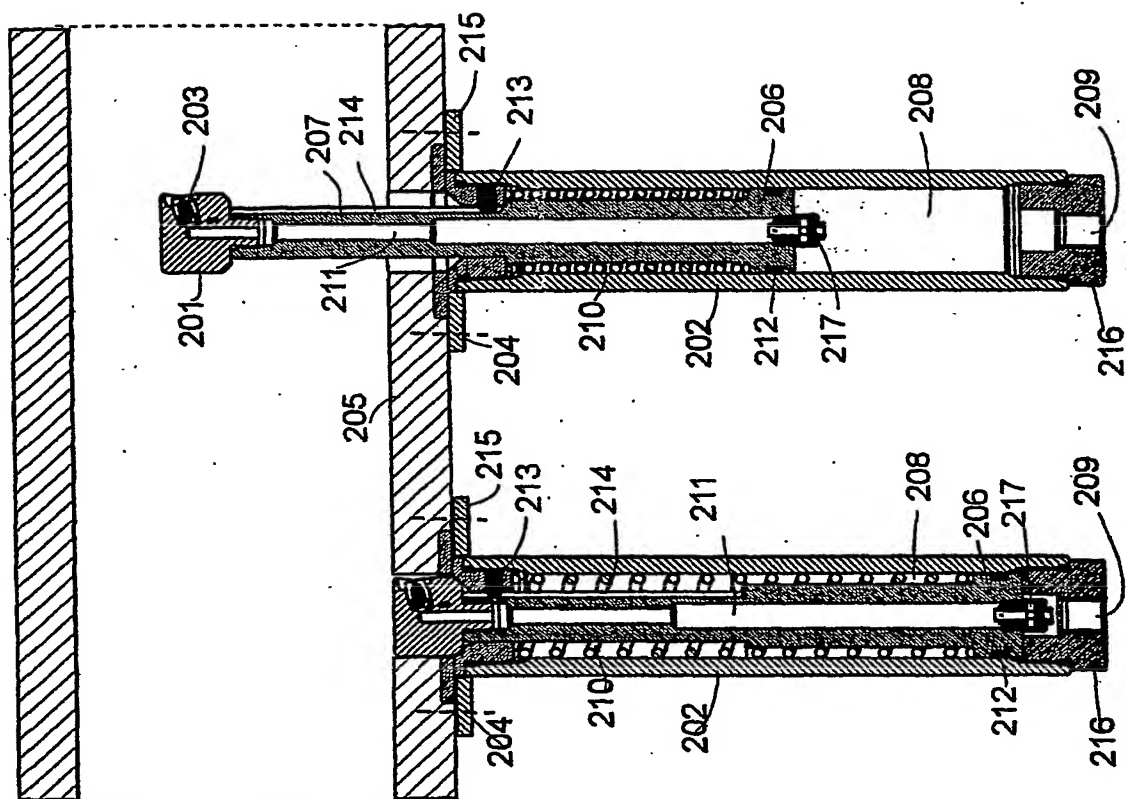


FIG 2 b

FIG 2 a

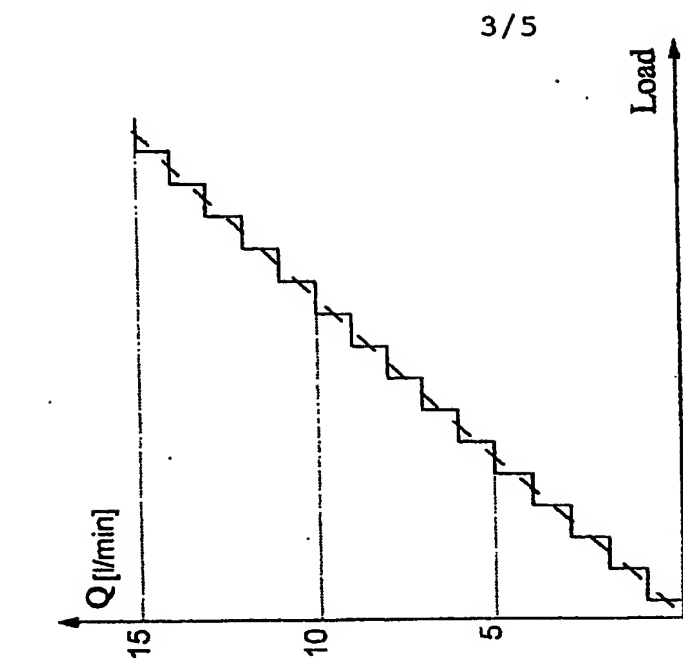


FIG. 3b

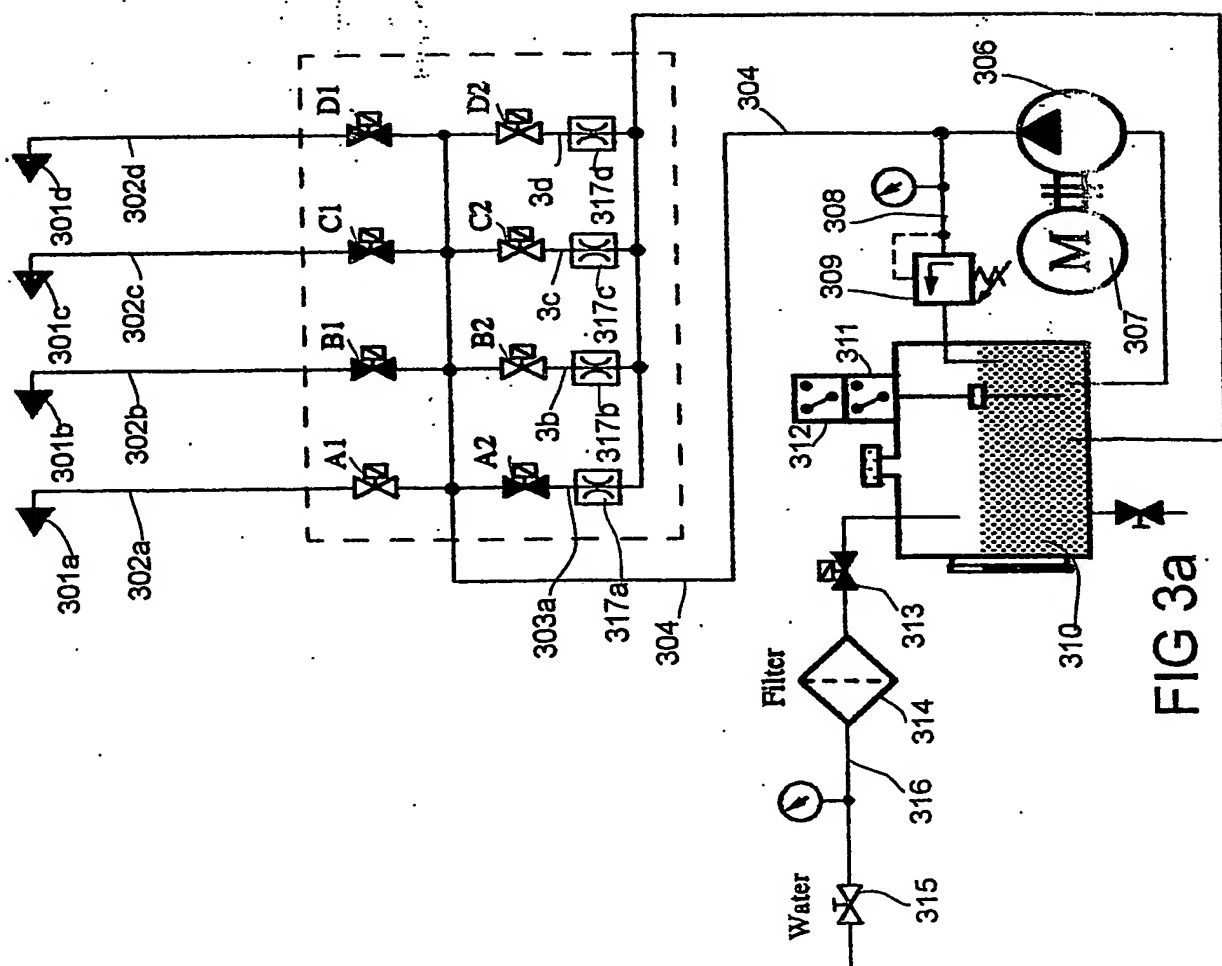
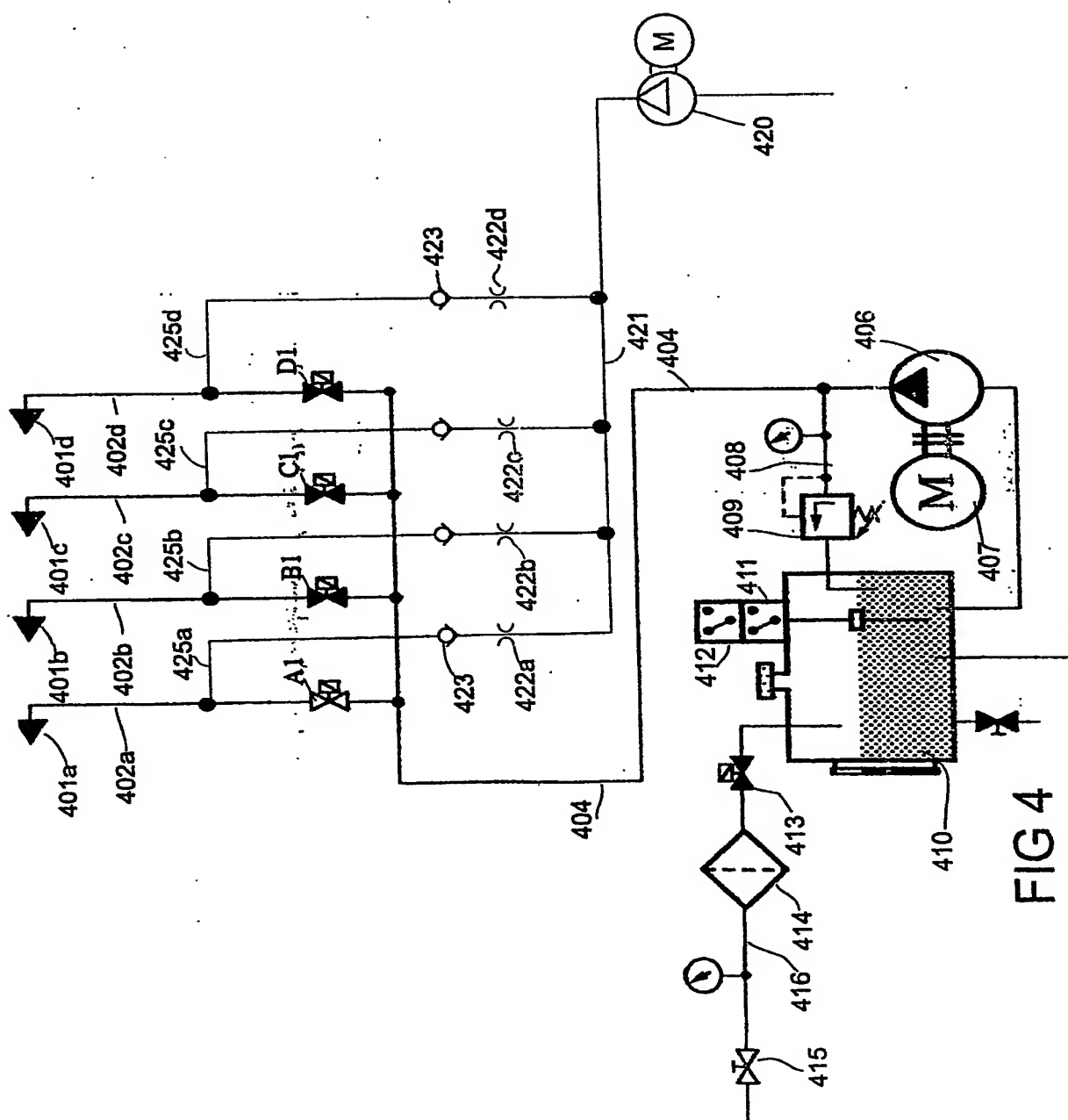


FIG 3a



5/5

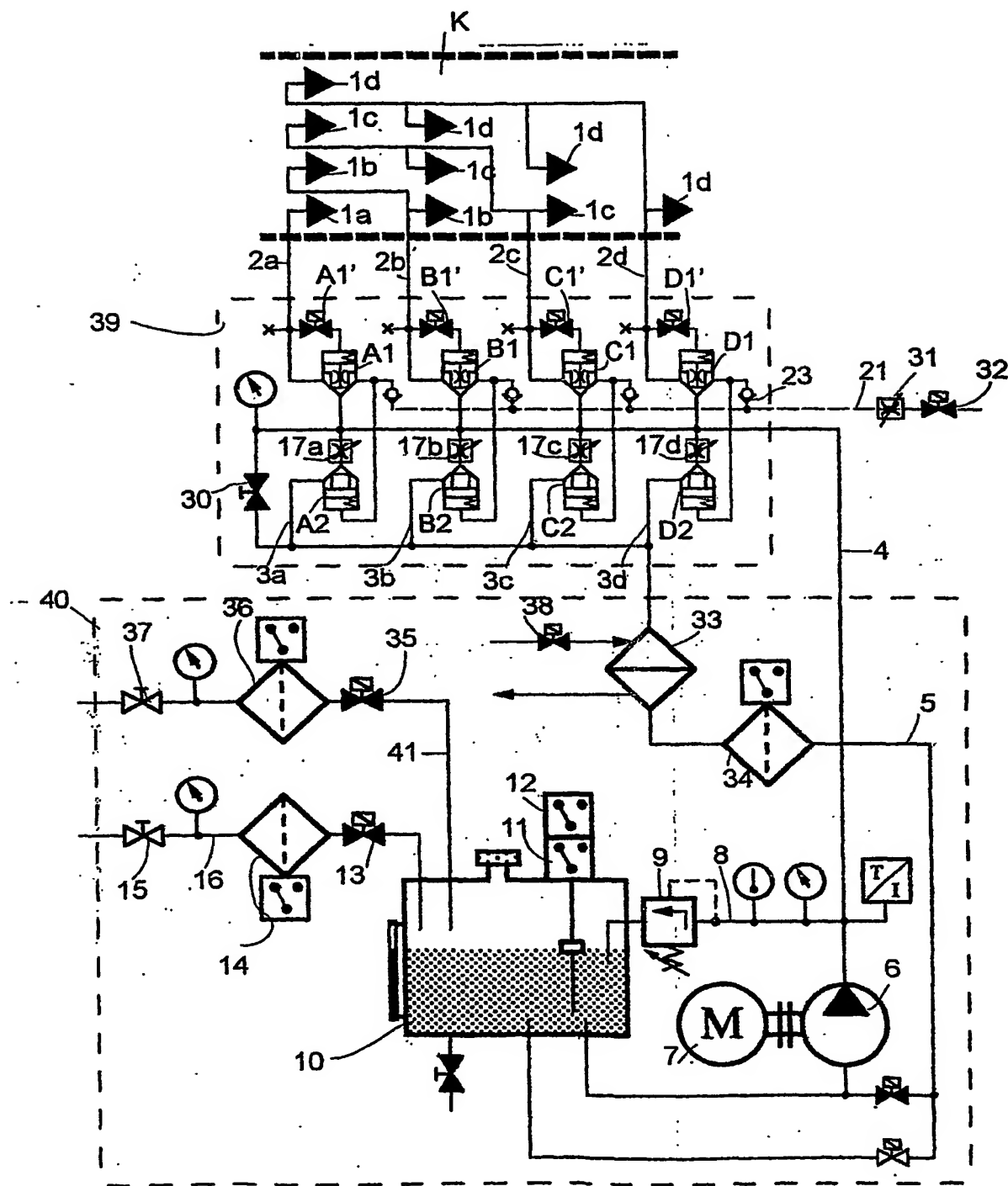


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 03/00303

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F02M 25/028

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 3405899 A1 (PESCHANEL, F.D.), 5 Sept 1985 (05.09.85), figure 1, abstract --	1-17
X	US 4377135 A (J. ABTHOFF ET AL), 22 March 1983 (22.03.83), column 1, line 15 - column 2, line 15, figure 1, abstract --	1-17
X	US 5148776 A (M.J. CONNOR), 22 Sept 1992 (22.09.92), column 2, line 49 - column 3, line 20, figures 1-10 --	1-17

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 July 2003

Date of mailing of the international search report

09 -07- 2003

Name and mailing address of the ISA/

Swedish Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 03/00303

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>US 4960080 A (J.S. O'NEILL ET AL), 2 October 1990 (02.10.90), column 2, line 25 - column 3, line 19, figures 1,2</p> <p style="text-align: center;">-- -----</p>	1-17

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/06/03

International application No.

PCT/FI 03/00303

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
DE	3405899	A1	05/09/85	NONE	
US	4377135	A	22/03/83	DE 2944318 A FR 2468753 A,B GB 2062755 A,B IT 1174310 B IT 8050010 D JP 56075951 A SE 8007654 A	14/05/81 08/05/81 28/05/81 01/07/87 00/00/00 23/06/81 03/05/81
US	5148776	A	22/09/92	NONE	
US	4960080	A	02/10/90	NONE	

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY (Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

10/511941

REC'D	17 JUN 2004
WIPO	PCT

Applicant's or agent's file reference 103977 TL	FOR FURTHER ACTION See Form PCT/IPEA/416	
International application No. PCT/FI2003/000303	International filing date (day/month/year) 16.04.2003	Priority date (day/month/year) 19.04.2002
International Patent Classification (IPC) or national classification and IPC F02M 25/028		
Applicant Marioff Corporation OY et al		

- This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
- This REPORT consists of a total of 3 sheets, including this cover sheet.
- This report is also accompanied by ANNEXES, comprising:
 - ☒ (sent to the applicant and to the International Bureau) a total of 3 sheets, as follows:
 - ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
 - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
 - ☐ (sent to the International Bureau only) a total of (indicate type and number of electronic carrier(s)) _____, containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

- This report contains indications relating to the following items:

- | | | |
|-------------------------------------|--------------|---|
| <input checked="" type="checkbox"/> | Box No. I | Basis of the report |
| <input type="checkbox"/> | Box No. II | Priority |
| <input type="checkbox"/> | Box No. III | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability |
| <input type="checkbox"/> | Box No. IV | Lack of unity of invention |
| <input checked="" type="checkbox"/> | Box No. V | Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement |
| <input type="checkbox"/> | Box No. VI | Certain documents cited |
| <input type="checkbox"/> | Box No. VII | Certain defects in the international application |
| <input type="checkbox"/> | Box No. VIII | Certain observations on the international application |

Date of submission of the demand 10.11.2003	Date of completion of this report 27.05.2004
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. +46 8 667 72 88	Authorized officer Dan Ionesco / JA A Telephone No. +46 8 782 25 00

Form PCT/IPEA/409 (cover sheet) (January 2004)

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.

PCT/FI2003/000303

Box No. I Basis of the report

1. With regard to the language, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ This report is based on a translation from the original language into the following language _____, which is the language of a translation furnished for the purposes of:

- ☐ international search (under Rules 12.3 and 23.1(b))
☐ publication of the international application (under Rule 12.4)
☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the elements of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

☐ the international application as originally filed/furnished

☒ the description:

pages 1-16 _____ as originally filed/furnished

pages* _____ received by this Authority on _____

pages* _____ received by this Authority on _____

☒ the claims:

pages _____ as originally filed/furnished

pages* _____ as amended (together with any statement) under Article 19

pages* 17-19 received by this Authority on 16.04.2004

pages* _____ received by this Authority on _____

☒ the drawings:

pages 1-5 _____ as originally filed/furnished

pages* _____ received by this Authority on _____

pages* _____ received by this Authority on _____

☐ a sequence listing and/or any related table(s) – see Supplemental Box Relating to Sequence Listing.

3. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages _____

☐ the claims, Nos. _____

☐ the drawings, sheets/figs _____

☐ the sequence listing (specify): _____

☐ any table(s) related to the sequence listing (specify): _____

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

☐ the description, pages _____

☐ the claims, Nos. _____

☐ the drawings, sheets/figs _____

☐ the sequence listing (specify): _____

☐ any table(s) related to the sequence listing (specify): _____

* If item 4 applies, some or all of those sheets may be marked "superseded."

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.

PCT/FI2003/000303

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)

Claims 1 - 17 YES
Claims _____ NO

Inventive step (IS)

Claims 1 - 17 YES
Claims _____ NO

Industrial applicability (IA)

Claims 1 - 17 YES
Claims _____ NO

2. Citations and explanations (Rule 70.7)

Amended claims have been submitted.

The documents cited in the International Search Report represent the prior art. The claimed invention stated in claims 1 - 17 is not anticipated by these documents. None of the documents or any relevant combination of them reveals a water spraying system as described by these claims.

According to the arguments stated above, the invention claimed in claims 1 - 17 is novel and considered to involve an inventive step. The industrial applicability of the claimed invention is obvious.

Claims

1. Water spraying system, especially for the humidification of the intake air of a piston engine to reduce nitrogen oxide emissions, said system comprising at least one nozzle (9, 10, 11, 12, 13) for spraying an aqueous liquid mist into the air intake duct (2) and means for conveying the liquid to be sprayed to the nozzle, c h a r a c t e r i z e d in that the system comprises means for accomplishing the injection of a spray of aqueous liquid mist with an adjustable temperature to at least one point in the air intake duct (2) depending on the load and/or speed of rotation and/or temperature of the engine.
2. Water spraying system according to claim 1, c h a r a c t e r i z e d in that the amount of aqueous liquid to be sprayed into the air intake duct (2) is distributed in the system to several nozzles (9, 10, 11, 12, 13).
3. Water spraying system according to claim 1 or 2, c h a r a c t e r i z e d in that the amount of aqueous liquid to be sprayed is distributed in the air intake duct (2) over a larger area to achieve an optimal vaporization, preferably to points with a high temperature and/or air flow or to their vicinity.
4. Water spraying system according to any one of claims 1 – 3, c h a r a c t e r i z e d in that the number of nozzles (9, 10, 11, 12, 13) in the system is adapted according to the required amount of liquid to be sprayed.
5. System according any one of claims 1 – 4, c h a r a c t e r i z e d in that the point of injection and/or direction of injection of the spray of liquid mist is adapted according to the required amount of aqueous liquid to be sprayed.
6. System according any one of claims 1 – 5, c h a r a c t e r i z e d in that the system comprises nozzles (9, 10, 11, 12, 13) having different properties, the number and/or type of nozzles spraying being varied according to the amount of liquid required.

7. System according any one of claims 1 – 6, characterized in that the several nozzles (9 – 13) in the system are arranged on the same mounting frame (6, 7).

5 8. System according any one of claims 1 – 7, characterized in that the system comprises a regulating apparatus, by means of which the injection action of at least some of the nozzles (9 – 13) can be controlled.

10 9. System according any one of claims 1 – 8, characterized in that the system comprises at least one valve element (13, 14), by means of which the liquid flow passage leading to one of the nozzles (9 – 13) is adjusted and/or opened/closed.

15 10. System according any one of claims 1 – 9, characterized in that the system comprises a regulating system, by means of which the pressure in at least one supply pipe (17) leading to the nozzles is kept at least nearly constant or at a predetermined level independently of the output of the pump.

20 11. System according any one of claims 1 – 10, characterized in that the system comprises an output regulating pump unit, by means of which the pressure is regulated by pressure control so that the pressure in at least one supply pipe (17) leading to a nozzle is constant.

25 12. System according any one of claims 1 – 10, characterized in that the system comprises a control system comprising a constant-output pump and controlling the pressure by means of a valve system to maintain a constant pressure in at least one supply pipe leading to a
30 nozzle.

13. System according any one of claims 1 – 12, characterized in that the system further comprises a system for cleaning the nozzles and/or keeping the nozzles clean.

35 14. System according any one of claims 1 – 13, characterized in that the pressure in the liquid supply piping is 10 – 300 bar.

15. System according any one of claims 1 – 14, characterized in that the droplet size of the water mist is typically below 200 micrometers.

5

16. System according any one of claims 1 – 15, characterized in that a second pressure medium, typically a gas, preferably air, is supplied to at least one nozzle.

10


17. System according any one of claims 1 – 16, characterized in that the apparatus comprises means for controlling the temperature of the liquid to be injected.

10/51941

PCT REQUEST

Original (for SUBMISSION) - printed on 16.04.2003 09:30:23 AM

VIII-4-1	<p>Declaration: Inventorship (only for the purposes of the designation of the United States of America) Declaration of inventorship (Rules 4.17(iv) and 51bis.1(a)(iv)) for the purposes of the designation of the United States of America:</p>	<p>I hereby declare that I believe I am the original, first and sole (if only one inventor is listed below) or joint (if more than one inventor is listed below) inventor of the subject matter which is claimed and for which a patent is sought.</p> <p>This declaration is directed to the international application of which it forms a part (if filing declaration with application).</p> <p>I hereby declare that my residence, mailing address, and citizenship are as stated next to my name.</p> <p>I hereby state that I have reviewed and understand the contents of the above-identified international application, including the claims of said application. I have identified in the request of said application, in compliance with PCT Rule 4.10, any claim to foreign priority, and I have identified below, under the heading "Prior Applications," by application number, country or Member of the World Trade Organization, day, month and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.</p>
VIII-4-1 -1	Prior applications:	20020756, FI, 19 April 2002 (19.04.2002)

		<p>I hereby acknowledge the duty to disclose information that is known by me to be material to patentability as defined by 37 C.F.R. § 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the PCT international filing date of the continuation-in-part application.</p> <p>I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.</p>
VIII-4-1 -1-1	Name:	SUNDHOLM, Göran
VIII-4-1 -1-2	Residence: (city and either US State, if applicable, or country)	TUUSULA, Finland
VIII-4-1 -1-3	Mailing address:	Ilmari Kiannon kuja 3
VIII-4-1 -1-4	Citizenship:	FI
VIII-4-1 -1-5	Inventor's Signature: (If not contained in the request, or if declaration is corrected or added under Rule 26ter after the filing of the international application. The signature must be that of the inventor, not that of the agent)	
VIII-4-1 -1-6	Date: (of signature which is not contained in the request, or of the declaration that is corrected or added under Rule 26ter after the filing of the international application)	16.4.2003

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